DETERMINING STREAM NETWORKS IN THE OZARK HIGHLANDS USING THREE SOURCES FOCUS: BOSTON MOUNTAIN ECOREGION

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Abstract

Land managers face unique challenges when utilizing digital information, the largest of which is the accuracy, detail and scale of the information. A prime example is the need for detailed representations of the hydrologic network when planning land management activities. Traditional sources for surface water information, such as topographic maps, possess inherent limitations. New technologies have made it possible to either model the stream network, or collect ground based spatial information digitally. In this study, a stream network was identified using three different sources: the 1:24,000 scale National Hydrography Dataset (NHD), a modeled stream network derived using a flow accumulation process performed on a 10 meter DEM coverage, and digitally collected, field based observations of stream channel locations using GPS technology. This study investigates the limitations of these different sources and their potential application with respect to land management applications in the Boston Mountain Ecoregion of Ozark Highland landscapes. This study concludes that the NHD stream network at the 1:24,000 scale under represented the actual stream network. The modeled stream network was found to represent 60% of the actual stream network and provided more detailed information regarding low order streams. Ground based field collection proved most accurate for identifying these features but was most time consuming and cost limiting.

INTRODUCTION

Land managers are often faced with a need for high-quality water resource information. This is essential when management activities require compliance with environmental laws and regulations. This evokes the question, what is the best source of data to use for identifying the stream network in a given area? Historically, topographic maps were used to identify major streams and tributaries. Smaller features, i.e. ephemeral streams, were interpreted from contour crenulations. This technique is time consuming, subject to errors, and may preclude identification of important low order streams. A consistent approach for identifying these stream networks can be developed based on landscape characteristics, such as watershed size and landforms (Williams et al., 2004).

Using a GIS environment and digital data sets, a reliable and consistent method for identifying stream networks will be demonstrated. A landscape model was used to derive a stream network. This modeled network was compared to the actual stream network through field observations. Finally, the modeled stream network was compared to the stream network represented on topographic maps. It was hypothesized that a modeled representation would identify ephemeral and intermittent stream channels not depicted on topographic maps. Such a process should predict the stream network in an efficient manner, with a known precision, for specific landscapes. If this process is validated, the resulting techniques will allow land managers to adapt to evolving regulations. Knowledge of the stream network will assist with site specific work prioritization, planning, or compliance monitoring.

STUDY AREA

This analysis focused on a 64,000 acre traditional Ozark Highland landscape in Arkansas. The study area was classified by the Arkansas Department of Environmental Quality as the Boston Mountain Ecoregion (APCEC, 2004). Characteristics unique to the Boston Mountain ecoregion, such as slope, aspect and relief, pose challenges for identifying hydrological features from map sources. The hydrological setting is such that blue line streams on 1:24,000 quadrangle maps are representative of large stream courses mapped using aerial photography. Intermittent and ephemeral channels are not indicated through map symbology. The field investigation that accompanies this analysis was performed on a limited subset (410 acres) within this ecoregion.

METHODS AND RESULTS

Three different sources of information were compiled for this study. Each source represented the spatial attributes of the stream network. The first consisted of traditional information available from topographic maps. The second was a modeled stream network based on landscape characteristics. The third resulted from field observations of stream channel locations. The modeled stream network was visually compared to topographic maps and further compared to field observations to determine the precision of this process. Finally, a broad quantitative comparison between the NHD stream network and the modeled stream network was conducted.

The USGS National Hydrographic Dataset (NHD) was derived from 1:24,000 quadrangle maps. This dataset represents the blue line streams found on maps and is the most reliable, widely available digital data set for hydrographic information. The NHD were used to represent the information available from topographic map sources (the blue lines).

A Digital elevation models (DEM) with a grid cell resolution of 32.8 feet was used to characterize the landscape for the modeling process. From this DEM a stream network was derived using a simple, flow accumulation process. This process identified the lowest neighboring cell for every cell in the set, to depict the potential flow path across the landscape surface. A network through this flow path was then assimilated using a contributing area threshold value to define the watershed characteristics for stream initiation. A threshold value of 20 acres was used for this study. The result from this process was a stream network with elements consisting of segments meeting the above criteria. Each network element was given a Strahler stream order classification (Strahler, 1957). This derived data source will be referred to as the modeled stream network.

The third data set consisted of field observations acquired using real-time GPS collected spatial data. A 410 acre subset of the study area was selected for detailed investigation. This was conducted using two transects that paralleled the hillside contour. As streams channels were intersected by the transects and positively identified as ephemeral streams (1-10 feet wide, have a defined bank and bed, and show signs of annual water flow), the locations were collected and stored for later comparative analysis. Data collection was accomplished using a Garmin® GPS III +, connected to a Dell Axim Pocket PC. The software package, Ozi Explorer CE, was used to derive a real-time position and store the locations of the intersected stream channels.

Modeled Stream Network vs. Landscape

The topographic maps reveal contour line crenulations that indicate swales in the landscape. Experience indicates that low-order, head water tributary stream channels typically occupy these landscape features. These segments are considered ephemeral streams, which flow in response to precipitation events. If the threshold for the modeling process is properly calibrated then the elements of the modeled network are expected to reasonably represent the existing stream channels. The modeled stream network was visually compared to the topographic maps and found to indicate streams within the respective locations. Every contour indention did not possess a stream network; a product of the threshold selected for the modeling process. This analysis highlights the potential for using a modeled stream network to identify stream locations based on landforms.

Modeled Stream Network vs. Field Observations

To determine if the modeled stream network is representative of the actual stream network, the modeled stream network was compared to the observed stream locations. Of the 15 stream channel intersections encountered during the field observations, nine were predicted by the modeled stream network, and six were not predicted. The model did not predict streams that were not encountered. This suggests that the modeled stream network is useful for providing a more detailed representation of the low order streams across the landscape. As a result of this analysis, the modeled stream network was found to depict 60 percent (by occurrence) of the ephemeral stream channels for this landscape, thus underestimating their existence. It is therefore reasoned that the threshold value used for the modeling process should be subjected to refinement.

Modeled Stream Network vs. NHD

A quantitative analysis was conducted to elucidate the practicality of using NHD data in planning exercises. The following assumptions were made; the modeled stream network accurately depicted actual conditions and account for 60 percent of the stream network length. Under this assumption the modeled stream network provides a proxy for the actual stream network and the NHD can be characterized with respect to the modeled network. According to the NHD data, there were 1,040,833 feet present in the stream network for the study area. The modeled stream network indicated 3,387,989 feet present in the stream network for the same area. This suggests that the actual stream network is roughly three times the extent identified on a topographic map.

Within a GIS environment the NHD data was buffered at successive 33, 66, 100, 1000, 2500, and 5000 foot widths. For each buffered area, a subset of the modeled stream network was selected from the total modeled stream network extent. These selected extents were summed to determine the total length and total number of the network elements for each stream order class within the various buffer widths.

The modeled stream network extent identified by the 33 foot width buffer was used to characterize the portion of the stream network represented by the NHD data. Table 1 indicates that fourth order streams, and higher, are almost entirely represented by the NHD data. The NHD data was also found to represent a large portion (greater than 79% by length and 89% by number) of the third order streams. At the second and first order classes, the representation falls below 50%, indicating the inability for NHD data to produce accurate information regarding these network segments. Therefore the stream network represented by blue lines on topographic maps are third order and greater in the real environment. The lowest order streams, in the most upper position of the landscape, are not well represented by the NHD data set.

Table 1 Modeled network characteristics at the 33 foot width buffer

Variable	Order	Percent of Total	Variable	Order	Percent of Total
Length	First	6%	Reaches	First	41%
	Second	31%		Second	58%
	Third	79%		Third	89%
	Fourth	96%		Fourth	98%
	Fifth	97%		Fifth	100%
	Sixth	93%		Sixth	89%
	Eighth	96%		Eighth	99%

To further investigate how low order streams are portrayed by NHD data, the modeled stream network extents captured by the successive buffer areas were examined. The length for first and second order, modeled streams are found to increase with distance from the NHD features. This is evident from figure 1 where network length for these two classes increase between the 100 and 1000 foot buffer widths. This is interpreted to result from portions of the stream network that exists as streams normal to the main, third order stream segments. Therefore, low order tributaries extend up hill slopes for ~ 1000 feet before bifurcating (evident in the change in slope above 1000 feet). This may be the result of first order streams developing high on the hillsides and then combining to flow downhill as second order streams. Beyond the 1000 foot distance the landscape supports streams that can accumulate together; below the 1000 foot distance, the hillsides produce a single channel moving normal to the surface.

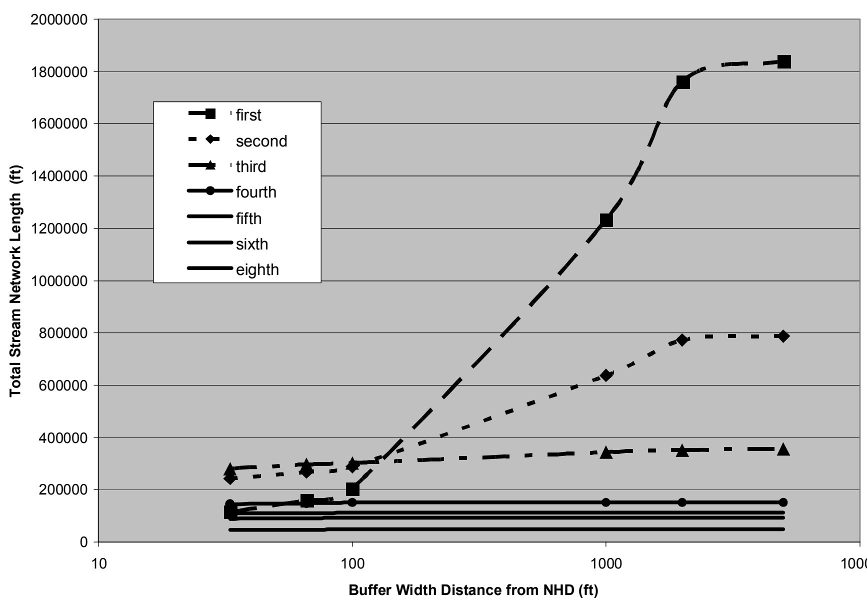

Figure 1 Length of modeled streams by order category within successive NHD buffer widths

CONCLUSIONS

Information regarding stream networks in the Boston Mountain ecoregion of Arkansas can be gathered through three different methods including topographic maps, modeled stream networks and direct field observations. A modeled stream network is useful for locating low order streams within the landscape. The modeling process described in this study used a threshold of 20 acres; resulting in a modeled stream network that represented approximately 60% of the actual stream network for this landscape. This threshold underestimates the presence of stream channels, but will not predict stream channels where they do not exist. The modeled stream network, without correction for underestimation, is approximately three times the length of the stream network represented by NHD data. NHD data in this landscape is representative of third order and greater streams under actual conditions. Low order stream initiation may be better determined using threshold values that are calibrated for landscape characteristics such as land type associations, slope, aspect, and geology.

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